HIGHWAY SUBSURFACE EXPLORATION

JULY, 1957

NO. 22

by

D.G. SHURIG

E.J. YODER

Joint Highway Research Project

PURDUE UNIVERSITY
LAFAYETTE INDIANA

Technical Paper

HIGHWAY SUBSURFACE EXPLORATION

TO: K. B. Woods, Director
Joint Highway Research Project — July 24, 1957

FROM: H. L. Michael, Assistant Director — File 6-14-5
Project C-36-36E

Attached is a technical paper entitled "Highway Subsurface Exploration" by D. G. Shurig and E. J. Yoder of our staff. The paper was presented at the 43rd Annual Purdue Road School in April and has been submitted for publication in the Proceedings.

It pertains to the operation and use of diamond core drilling machines, power augers and electrical resistivity units for highway subsurface exploration.

The paper is presented for the record.

Respectfully submitted,

Harold L. Michael

Harold L. Michael, Assistant Director

HLM:bjk

Attachment

cc:
D. S. Berry
A. K. Branham
J. R. Cooper
W. L. Dolch
W. H. Goetz
J. T. Hallett
F. F. Havey
G. A. Hawkins
G. A. Leonards
J. F. McLaughlin
H. L. Michael
R. D. Miles
R. E. Mills
B. H. Petty
C. E. Vogelgesang
J. L. Waling
J. E. Wilson
K. B. Woods
E. J. Yoder

Technical Paper

HIGHWAY SUBSURFACE EXPLORATION

by

D. G. Shurig, Research Assistant
E. J. Yoder, Research Engineer

Joint Highway Research Project
Project C-36-36E
File 6-14-5

Purdue University
Lafayette, Indiana

July 24, 1957

HIGHWAY SUBSURFACE EXPLORATION

D. G. Shurig, Research Assistant
E. J. Yoder, Research Engineer
Joint Highway Research Project
Purdue University

Introduction

This paper pertains to the operation and use of diamond core drilling machines, power augers and electrical resistivity units for highway subsurface exploration. The use of these machines for investigating various types of shallow earth surface conditions is considered.

Figure 1 shows a typical core drilling machine. Its essential parts are (1) a power unit (2) a hoist and derrick pole for lowering and raising drilling tools and to operate drop hammers for driving casing and sample spoons (3) a hydraulic swivelhead which supplies the rotational motion and downward feed to the drill rods and (4) a water pump (not shown) to pump water to the drilling bit for the purpose of keeping it cool and forcing the waste grindings up out of the hole.

Figure 2 shows how rock core drill rigs can be used to advance a hole in soil and take soil samples. In method (A) the casing is driven several feet into the ground and the material inside the casing is removed by the rotating chopping bit and forced wash water. If a change in color of the returning was water is noticed or if some physical change in the soil grains is observed, the cleaning operation should be stopped and a two inch split sppon inserted for a standard penetration test. This test is performed by dropping a 140 pound hammer 30 inches onto the spoon and determining the number of blows required to drive the spoon a distance of one foot. The spoon is driven six inches though any loose material before the test is

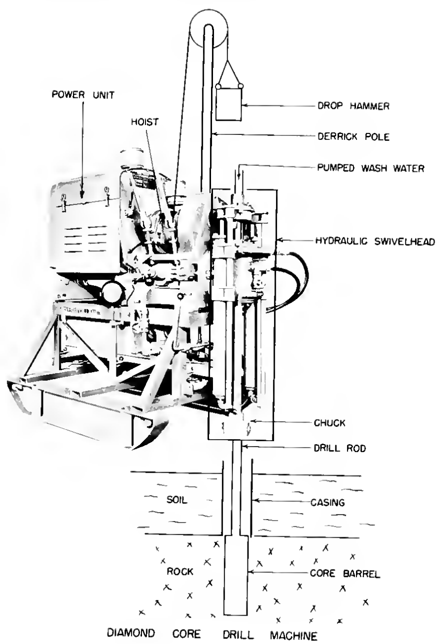


FIG. 1 DIAMOND CORE DRILL MACHINE

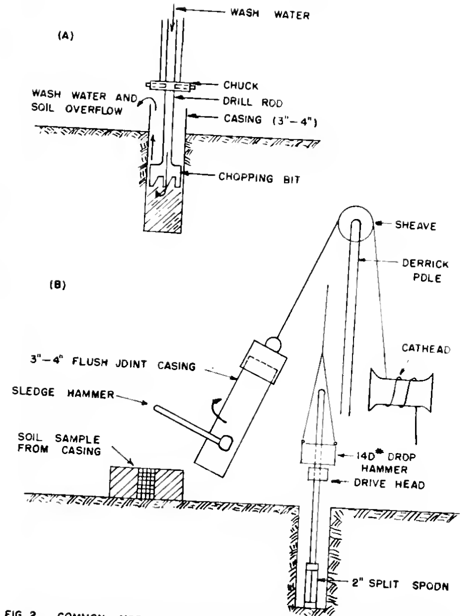


FIG. 2 COMMON METHODS OF ADVANCING AND CLEANING BORE HOLES (A) CHOPPING & WASHING (B) DRIVING CASING OR LARGE SPOON

FIG. 2 COMMON METHODS OF ADVANCING AND CLEANING BORE HOLES
(A) CHOPPING AND WASHING
(B) DRIVING CASING AND LARGE SPOON

actually started.

The second method of advancing the hole can only be used in cohesive soils above the water table. It is done by driving casing (usually 3 or 4 inches in diameter) and then pulling the casing with the soil adhering to the inside. By jarring and vibrating the casing with a sledge hammer the soil can be removed as shown. Any changes in the removed soil can be sampled but there will be no penetration test data for it. The method is best suited for deep homogeneous soils where the samples might be taken at five foot intervals. If a casing with a 4-inch diameter is used, a soil core, which is approximately one foot long and which has a soil grain size smaller than the number four sieve, can be obtained and will supply enough material for a Proctor compaction test.

In a research report "Subsurface Exploration and Sampling of Soils for Civil Engineering Purposes," Dr. Hvorslev describes specific methods and numerous tools for the sampling of all types of soils at various moisture contents. Most of these soil sampling tools described by Dr. Hvorslev can be adapted to the core drilling machines.

For taking rock cores single and double tube core barrels fitted with core retainers are used. The schematic drawings in Figure 3 show how the barrels and retainers function. Note how in the single tube core barrel the core is exposed to the downward flowing wash water and to abrasion on all parts of the core. Therefore, the single tube core barrel should not be used for materials which are subject to erosion, slaking or excessive swelling.

The wedges are sections of circular core retainers. As the core barrel goes down and the rock core moves upward into the barrel the retainers are held in the up position as shown in the drawing on the left. When the barrel is withdrawn and the core tends to fall out of the barrel,

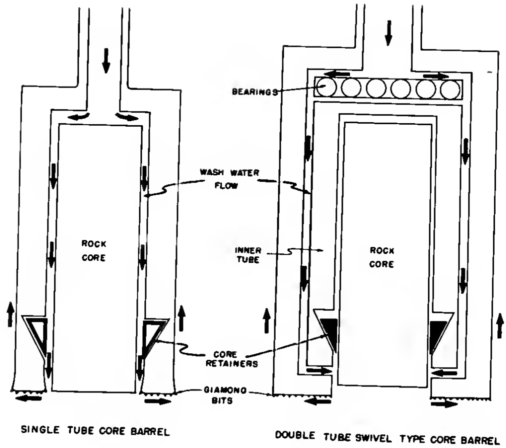


FIG. 3 DIAMOND BIT CORE BARRELS

the retainers drop and lock the core in the barrel as indicated in the right hand drawing.

Occasionally the retainers do not function and so the core occasionally slips out of the barrel. The retainers are also subject to malfunction in which they jam the core entering the bit and block the barrel.

A double tube swivelhead core barrel has the inner tube riding on bearings in the barrel head so that it does not rotate with the outer barrel. The stationary inner tube protects the core from water erosion and also decreases inside friction, abrasion, and transmission of torsional forces to the core. The double tube core barrel is commonly used for sampling rock that is soft, friable, non-uniform, fissured, and in general when the diameter of the core is small.

The main criteria for good drilling is the percentage of core recovered or its counter part - percent core loss. Each time the core barrel is inserted into the hole and advanced a few feet, the percent of core recovered is found by measuring the length of rock core removed from the barrel, dividing this by the advance of the barrel, and multiplying by 100.

The engineer in charge of the field exploration work should be able to judge whether high core loss is due to the condition of the rock, faulty equipment, or poor drilling. Following are some means that might be used when the highest possible core recovery is desired and when added expense is justified.

(1) Employment of an experienced and skilled crew.

(2) Use of a double tube swivel type core barrel.

(3) Make short drilling runs of one to three feet or pull the barrel up as soon as it blocks. Blocking is often indicated by a clicking, jerking, or chattering of the drill rods.

If a piece of hard rock blocks the barrel entrance just at the start of a run and then the barrel is advanced five to ten feet it is possible to grind away nearly the entire five to ten feet of core. When core loss is high in hard sound rock, like fresh granite, it is usually due to blocking of the barrel. The barrel can also be blocked by completely filling it with core. If drilling is continued the rock at the barrel entrance will be ground away.

(4) A procedure called dry blocking or burning in is used when the rock being cored is soft and friable or easily eroded. Even when using a double tube core barrel the diameter of the rock core may be reduced so much that the core slips through the core retainer. For this situation the wash water can be shut off and the barrel advanced several inches. If the grindings are not washed away they will form a wedge between the core and the inner wall of the barrel entrance and so prevent the core from slipping out of the barrel when withdrawn. This dry blocking should be requested only of an experienced driller as the expensive diamond bits can be easily damaged from the high heat generated.

(5) Keep vibration of drilling tools to a minimum. Excessive vibration of drill rods and core barrels has a tendency to break up the core. The broken pieces erode faster and they also increase the possibilities of jamming the barrel. Excessive vibration can be caused by many factors but it is primarily due to worn equipment and careless drilling.

(6) Increase the diameter of the barrel and so the core. Since the torsional moment of resistance of the core increases with the

cube of its diameter, an increase in diameter is very effective in reducing breakage and increasing core recovery.

In Figure 4, (A), (B), (C), (E), (F), and (G) show typical soil augers and cutter heads developed primarily for power pole or post hole and blast hole drilling. (A) shows a single flight auger for boring shallow holes. (C) shows a three flight auger which can carry a greater pay load and so reduces the number of trips from the bottom of the hole to the ground surface. (B) shows a continuous flight auger which might be used to drill over a hundred feet deep by the addition of sections. (F) illustrates a cutter head that can be attached to continuous flight drills for boring in soft soils. Figure (E) illustrates a cutter head with replaceable bits for drilling in rock of soft to medium hardness. Bits tipped with tungsten carbide are used when drilling blast holes in rock.

Figure 5A shows how a single flight auger can be used, to obtain a representative sample of a relatively thin soil layer from a depth which can be determined within about six inches. If a large diameter cutter head is used an accessible test pit can be bored permitting visual inspection and the removal of undisturbed samples from the wall of the hole. The main disadvantages are that only cohesive soils above the water table can be sampled otherwise the hole will cave. A second disadvantage is that the depth of sampling is limited to about twenty feet due to the length of the Kelly bar.

Advantages of the continuous flight auger, Figure 5B, for exploratory work is that it can penetrate to great depths in most types of soil, both cohesive and non cohesive. The main disadvantages are (1) as penetration increases, it becomes more difficult to determine the exact depth from which the soil discharged at the surface, was actually excavated and

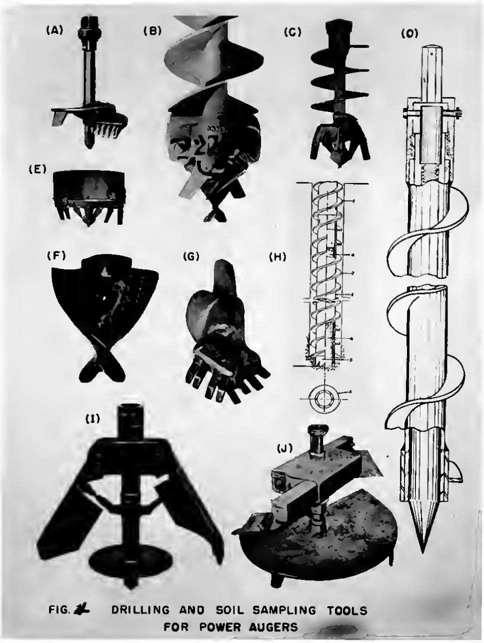


FIG. 4 DRILLING AND SOIL SAMPLING TOOLS FOR POWER AUGERS

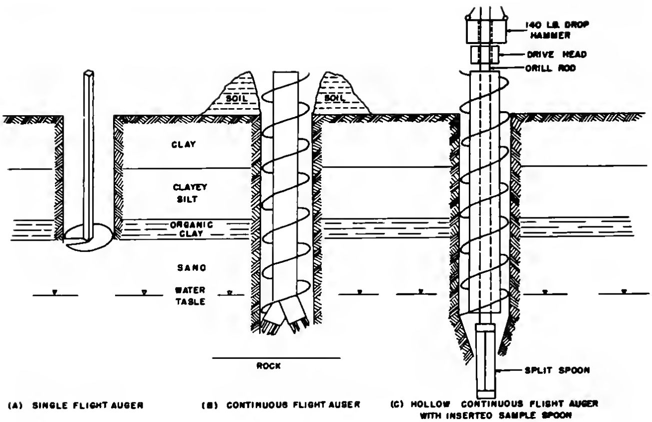


FIG. 5 METHODS OF SAMPLING WITH POWER AUGER TOOLS

(2) there can be some degree of mixing of the soil [illegible] resulting in a non-representative sample. [illegible] that the continuous flight auger be used in deep [illegible]

The hollow continuous flight auger, which is fitted with a [illegible] point when the hole is being advanced, is one of the few power auger tools originally developed for exploration work. See [illegible] with various sampling devices, representative samples from exact [illegible] depths can be obtained from cohesive and non cohesive soils above or below the water table.

Beside these standard and special power auger tools, many of the standard soil sampling tools and soil testers can be adapted to the augers. A thin-walled sampler, for an undisturbed sample, can be attached to the Kelly bar, or a string of continuous flight augers, and [illegible] smoothly into the soil by means of the hydraulic ram. The Kelly [illegible] of flights, and ram can also be used to operate a vane shear tester to obtain the shear strength of soft clays in place, both in the undisturbed and remolded states. A drop-hammer apparatus can be used for taking split spoon samples, making standard penetration tests, and for probing with various types of penetrometers.

In a study of the combined use of diamond core drilling machines, power augers and electrical resistivity units on the Northeastern Extension of the Pennsylvania Turnpike System (Philadelphia north 100 miles to Scranton) a definition of sound and unsound rock relative to highway cut areas was devised. A homogeneous rock mass was called sound if any one of the following conditions was satisfied.

(1) If the rock required blasting for excavation;

(2) When the rock resisted and withstood the efforts of a tractor-drawn rooter;

(3) When during exploration it yielded [illegible] re- covery greater than 50 percent (plus [illegible]) drilled with a single tube core [illegible];

(4) If the rock was able to stand permanently [illegible] a very minimum of ravelling, at a slope of 3/4 to 1 or [illegible].

Using this criteria for sound rock and Terzaghi's definition of soil for civil engineers, it was possible to divide all the cut areas on the Turnpike into six groups. The six groups are illustrated in Figure 6 and are used primarily to compare and explain the accuracy of locating the top of sound rock by diamond core drilling rigs, power augers, and electrical resistivity units. Classification of the cuts also demonstrates shallow conditions of the surface of the earth with which the civil engineer works.

The core drilling machine, with an array of auxiliary soil and rock sampling tools, quite naturally produced the most accurate and most complete data in each of the six groups. In over 75 percent of the borings, the top of sound rock was indicated by casing refusal. For the remaining 25 percent, the top of sound rock was located below the bottom of the casing at a point where the core recovery became and stayed greater than 50 percent.

Since results with the core drill were excellent in all cases it remains to compare only the accuracy of the auger and resistivity for locating the top of sound rock in each group.

The first group of cuts consisted of those composed entirely of soil and the second group, those composed of both soil and sound rock. In the latter group, the transition from soil to rock was fast - perhaps one or two feet of loose and weathered rock. Quartzites, hard sandstones

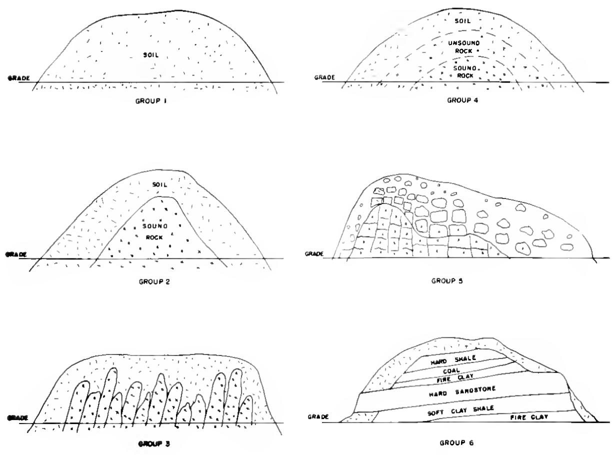
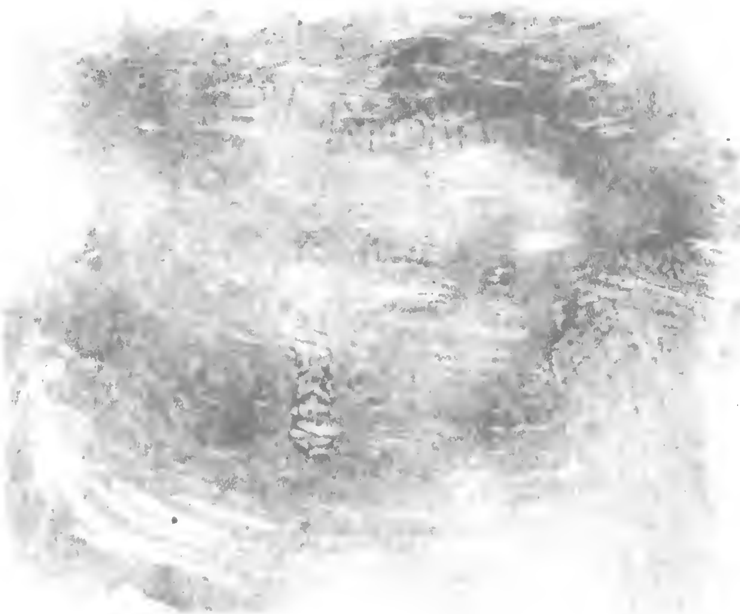


FIG. 6 SIX SHALLOW EARTH SURFACE CONDITIONS



and siliceous and intrusive igneous rock often [illegible]. Location of the top of sound rock as given by the power auger and resistivity for these two groups was excellent.

In the third category of cuts the top of sound rock was very irregular. This condition was found primarily in steeply dipping, thin, interbedded, clayey limestone and siliceous limestone differentially weathered. For this group, accuracy of both the auger and resistivity was good. The resistivity gave an average depth to the top of sound rock while the pin point probing of the auger indicated the saw-tooth rock profile. For cuts of this type auger borings and resistivity soundings should be spaced about every 50 feet along the center line of each separate pavement. Ordinarily spacings of 100 and 200 feet are used.

Group four, formed primarily by clay shales, shales, and soft sandstones, is made up of three layers. A top layer of soil grades slowly into a layer of highly weathered rock and this weathered, or unsound rock, grades slowly and imperceptively into a layer of sound rock. For these conditions resistivity results were poor to fair while auger results were good to excellent.

After excavation of the three layered types of cuts was completed, it was determined that auger refusal had meaning and yielded certain information.

(1) Above the point of auger refusal the material usually did not require blasting and the cut slope should be designed as a soil slope.

(2) Below refusal a homogeneous rock mass will probably require blasting and stand permanently on a 3/4 to 1 slope or steeper slope.

(3) It was also learned that auger refusal was very near to where core recovery became greater than 50 percent and also very near to where tractor drawn rooters met refusal. In other words, the auger was able to locate the top of sound rock in most gradationally weathered, homogeneous rock formations.

The fifth group of cuts was the boulder type. In very general terms this type might consist of 50 percent boulders, 25 percent soil and 25 percent sound rock. Diabase cuts are good examples. The best procedure for this condition is to use all three machines and increase the number of borings or soundings of each and use only the data that appears most reasonable and logical from a geologic viewpoint.

For the sixth group, interbedded sound and unsound rock, as found in most of the soft coal regions, auger and resistivity data were practically worthless for highway work. For this condition the engineer should use core drilling machines, essentially alone, and concentrate on high core recovery. At certain depths where core recovery is extremely low attempts should be made to take spoon samples. Any recovered core that appears unstable, should be split and parts of it subjected to wetting and drying and freezing and thawing tests.

In conclusion it should be pointed out that the choice of exploration equipment which should be used will depend on the anticipated subsurface conditions. The engineer should first make a survey utilizing, geological and soils literature, aerial photographs, and field inspection. These data will then determine the best type of exploration equipment to use.

BIBLIOGRAPHY

1. Cummings, [illegible] Diamond Drill Handbook, [illegible] Canada Ltd. [illegible] Ontario, Canada, [illegible]

2. Hvorslev, M. J., "Subsurface Exploration and Sampling of Soils for Civil Engineering Purposes," U. S. [illegible] Experiment Station, Vicksburg, Mississippi, 1949.

3. "Core Drills and Equipment," Catalog, [illegible] Scranton, Pennsylvania.

4. "Buda Earth Drills," Catalog, Buda [illegible] Manufacturing Company, Harvey, Illinois

5. "Mobil Drill," Catalog, Mobile Drilling, Incorporated, Indianapolis, Indiana.